Fisheries and Oceans Canada | Pêches et Océans Canada
Science | Sciences

Canadian Science Advisory Secretariat (CSAS)

Proceedings Series 2013/036

Central and Arctic Region

Proceedings of the recovery potential assessment of Western Silvery Minnow (*Hybognathus argyritis*)

March 23-24, 2011

Lethbridge, AB

Chairperson Kathleen Martin

Editor Lia Kruger

Fisheries and Oceans Canada
Freshwater Institute
501 University Crescent
Winnipeg MB R3T 2N6
Canada

November 2013

Canada

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

Published by:

Fisheries and Oceans Canada
Canadian Science Advisory Secretariat
200 Kent Street
Ottawa ON K1A 0E6

http://www.dfo-mpo.gc.ca/csas-sccs/
csas-sccs@dfo-mpo.gc.ca

© Her Majesty the Queen in Right of Canada, 2013
ISSN 1701-1280

Correct citation for this publication:

DFO. 2013. Proceedings of the recovery potential assessment of Western Silvery Minnow (*Hybognathus argyritis*); March 23-24, 2011. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2013/036.

TABLE OF CONTENTS

SUMMARY iv

SOMMAIRE iv

INTRODUCTION 1

DISCUSSION 1

- Species Information 2
- Taxonomy 2
- Species Biology and Ecology 2
- Historic and Current Distribution and Trends 3
- Historic and Current Abundance and Trends 5
- Habitat Requirements 5
- Residence 6
- Recovery Targets, Recovery Times and Minimum Area for Population Viability 7
- Threats to Survival and Recovery 9
- Mitigations and Alternatives 13
- Sources of Uncertainty 13
- Other Considerations 14

REFERENCES CITED 14

APPENDIX 1: TERMS OF REFERENCE 16

APPENDIX 2: MEETING PARTICIPANTS 17

APPENDIX 3: MEETING AGENDA 18

SUMMARY

The Western Silvery Minnow (*Hybognathus argyritis*) was listed as Threatened on Schedule 1 of Canada's *Species at Risk Act* (SARA) in 2003. In April 2008, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-assessed and designated Western Silvery Minnow as Endangered and now it is being considered for up-listing under the SARA. Fisheries and Oceans Canada (DFO) Science was asked to undertake a Recovery Potential Assessment (RPA) to inform the development of recovery documents, and to support decision-making with regards to up-listing and SARA agreements and permits. A Science advisory meeting was held on March 23 and 24, 2011 in Lethbridge, Alberta, to conduct the RPA. Meeting participants were from DFO Science and Habitat Management sectors of the Central and Arctic Region, and specialists from Alberta Sustainable Resource Development, Alberta Environment and Montana State University.

This Proceedings report summarizes the relevant discussions and presents the key conclusions reached at the meeting. The Science Advisory Report and two supporting Research Documents, resulting from this advisory meeting, are published on the DFO Canadian Science Advisory Secretariat (CSAS) Website.

Compte rendu de l'évaluation du potentiel de rétablissement (ÉPR) à l'échelle régionale du méné d'argent de l'Ouest (*Hybognathus argyritis*)

SOMMAIRE

Le méné d'argent de l'Ouest (*Hybognathus argyritis*) a été inscrit à la liste des espèces menacées au Canada de l'annexe 1 de la *Loi sur les espèces en péril* (LEP) en 2003. En avril 2008, le Comité sur la situation des espèces en péril au Canada (COSEPAC) a réévalué son statut et a désigné l'espèce comme étant menacée au Canada. À l'heure actuelle, on envisage d'élever son statut en vertu de la LEP. Une réunion de consultation scientifique régionale s'est tenue les 23 et 24 mars 2011 à Lethbridge, en Alberta. La réunion avait pour but de fournir des avis scientifiques sur le potentiel de rétablissement du méné d'argent de l'Ouest à partir du cadre d'évaluation du potentiel de rétablissement (EPR) de Pêches et Océans Canada (MPO). Les avis découlant de cette réunion d'EPR peuvent servir de base à l'élaboration de documents en matière de rétablissement et à la prise de décisions en ce qui a trait à l'élévation du statut de l'espèce et à la délivrance de permis, aux ententes et aux conditions connexes conformément à la LEP. Parmi les participants à la réunion, on comptait les secteurs des Sciences et de la Gestion de l'habitat de la région du Centre et de l'Arctique ainsi que des spécialistes du ministère du Développement durable des ressources de l'Alberta, du ministère de l'Environnement de l'Alberta et de la Montana State University.

Le présent compte rendu résume les discussions tenues et expose les révisions à apporter aux documents de recherche connexes. L'Avis scientifique et les documents de recherche à l'appui découlant de la présente réunion de consultation scientifique seront publiés sur le site web du Secrétariat canadien de consultation scientifique du MPO.

INTRODUCTION

The Western Silvery Minnow (*Hybognathus argyritis*) was added to Schedule 1 of the *Species at Risk* Act (SARA) as Threatened in June 2003. In April 2008, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-examined and assessed the status of the Western Silvery Minnow as Endangered due to its restricted range, the increasing frequency and severity of drought conditions and uncertain future of flow regimes in the Milk River. In advance of making a listing decision regarding up-listing Western Silvery Minnow on Schedule 1 to Endangered, and to inform development of an action plan and to support decision-making with regards to the SARA agreements and permits, a Recovery Potential Assessment (RPA) was conducted on March 23-24, 2011.

The purpose of the meeting, as described in the Terms of Reference (Appendix 1), was to evaluate the recovery potential of the Western Silvery Minnow. The RPA is a science-based peer review that assesses the current status of the Western Silvery Minnow and possible recovery targets, what is known about its biology, habitat and threats to the species or its habitat, and potential mitigation measures or alternatives to the threats and scope for human-induced mortality from threats. (Full details about the RPA process are available on the Canadian Science Advisory Secretariat (CSAS) website in DFO 2007a, b.)

Meeting participants (Appendix 2) included DFO Science and Habitat Management sectors, Alberta Environment, Alberta Sustainable Resource Development and a fish expert from Montana State University. DFO drafted two working papers, that later became Research Documents, to serve as the basis for the RPA. They were distributed to participants in advance of the meeting. Appendix 3 shows the agenda generally followed during the meeting.

This Proceedings report summarizes the relevant meeting discussions and presents the key conclusions reached. Science advice resulting from this meeting is published in the CSAS Science Advisory Report (SAR) series and the supporting data analyses are published in the Research Document series.

DISCUSSION

The Chair provided an overview of the processes that the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) uses to assess wildlife designations, the federal government lists species under the SARA, and DFO conducts RPAs. An overview of the COSEWIC assessment of the Western Silvery Minnow and an explanation of the purpose for, and contents of, an RPA was provided.

Two working documents were reviewed during the RPA meeting: first, a modelling paper that provided information related to recovery targets and times, minimum area for population viability and allowable harm, and a second r paper that contained all other information relevant to an RPA. Participants began by discussing the non-modelling paper; no formal presentation was given.

Working paper: Information in support of a Recovery Potential Assessment of Western Silvery Minnow (*Hybognathus argyritis*) in Alberta

Author: D. Watkinson

Abstract[1]

In April 2008, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-examined and designated Western Silvery Minnow (*Hybognathus argyritis*) as Endangered. This freshwater fish is restricted to the Milk River in Southern Alberta, a region characterized by drought conditions of increasing frequency and severity. While the future of flow regimes associated with the St. Mary's diversion canal and proposed water storage projects are uncertain, consequences of these activities have the potential to significantly affect the survival of the species. Rescue effect from U.S. populations is not possible (COSEWIC 2008). The Western Silvery Minnow is listed as Threatened under the *Species at Risk Act* (SARA). Prior to a listing decision, Fisheries and Oceans Canada (DFO) was asked to undertake a Recovery Potential Assessment (RPA). This RPA summarizes our current understanding of the distribution, abundance and population trends of Western Silvery Minnow in Alberta. Identification of threats to both the minnow and its habitat, and measures to mitigate these impacts are also reported. This information may be used to influence scientific and socio-economic elements of the action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions under the SARA.

Discussion

The document was reviewed, section by section, during the meeting and a number of editorial changes were made. Discussions related to each topic are described below.

SPECIES INFORMATION

The Western Silvery Minnow was initially assessed by COSEWIC as Threatened but recently reassessed as Endangered due to its restricted range, the increasing frequency and severity of drought conditions and uncertain future of flow regimes in the Milk River. It is not known whether the federal government will up-list this species under the SARA to Endangered. Regardless, a change from Threatened to Endangered would not change the prohibitions and protective measures required under the Act.

TAXONOMY

The Rio Grande Silvery Minnow (*Hybognathus amarus*) had not been mentioned in this section of the working paper because it is geographically isolated from the other six species in the genus. Regardless, participants agreed that it should be mentioned as it is the only minnow species in the group not included.

SPECIES BIOLOGY AND ECOLOGY

It was agreed that several subsections in the non-modelling working paper should be combined into a new subsection called Species Biology and Ecology.

Specific text about distinguishing characteristics was corrected or revised. The eye of this species is relatively large, not small, in comparison to other *Hybognathus* species in Canada. Additionally, the Western Silvery Minnow has a basioccipital process that is longer than it is

[1] Updated following the meeting incorporating comments and reanalysis.

wide, but its larger comparative width distinguishes it from Brassy Minnow (*Hybognathus hankinsoni*) and Plains Minnow (*Hybognathus placitus*).

Watkinson reported that longevity is five years in Western Silvery Minnow in the Milk River based on fin ray analysis from a very small sample size. The modelling analysis used four years for longevity. Pflieger (1997) reported a maximum age of 5.5 years for this species in Missouri. More information may be available in the recovery strategy.

Stomach contents of 20 Milk River specimens were collected in May 2005 or 2006 for diet analysis. The year(s) will be confirmed and corrected as necessary. Full references will be provided for Robison and Buchanan 1988 and Sublette et al. 1990, which were missing from the Literature Cited section of the working paper.

Participants discussed what is known about the tolerance of Western Silvery Minnow to environmental conditions. They appear to be tolerant of high turbidity and water temperatures and low dissolved oxygen levels. The reference in the working paper to low water temperature was deleted because all fishes in Canada are tolerant of low water temperatures. It was noted that Plains Minnow is more tolerant than other cyprinids not just Western Silvery Minnow. Ostrand and Wilde (2001) reported on the tolerance of Plains Minnow so their paper will be cited in this section.

Significance of the species was discussed. Until recently, Western Silvery Minnow could be used for bait, but since few people actively fished the Milk River the likelihood of it being used as bait was probably low. In 2002, the species was placed on the prohibited list of the Alberta General Sportfishing Regulations.

HISTORIC AND CURRENT DISTRIBUTION AND TRENDS

The second paragraph in this section was revised for clarity. The distance on the Milk River between the Canada/U.S. border and the Fresno reservoir, in Montana, is about 75 river km. Given that Western Silvery Minnow are very abundant in that stretch of the river, a rescue effect for the Canadian population is possible. Sampling in the 2000s expanded our knowledge of the distribution of this species to the lowermost 220 km of the Milk River in Canada. A record for Western Silvery Minnow was reported for the Saskatchewan River by Scott and Crossman (1973), but no museum specimen, or actual fish, was preserved. Nelson and Paetz (1992) suspected that data point was the result of a bait bucket transfer rather than an authentic record. Alternatively, the fish may have been misidentified.

The distribution of this species has declined extensively in areas of the United States over the past century, but there is no evidence of declining distribution in Canada. Water diversion through the Saint Mary Canal since 1917 has significantly altered the flow regime in the North Milk and Milk rivers, but it is not known whether that altered the distribution of this species. Western Silvery Minnow have been found further upstream in recent years but that may be related to sampling effort.

In Montana, there are museum records for this species in Poplar River and Big Muddy Creek. The Big Muddy is the next basin east of the Poplar. There were a couple of records from Poplar River within about 50-65 km of the Canada/U.S. border. Records are located farther downstream in Big Muddy Creek. More recent surveys conducted in those two waterbodies between 1999 and 2007 did not collect Western Silvery Minnow so they may have declined in those systems. Western Silvery Minnow may occur in the province of Saskatchewan in tributaries of the Milk River.

A participant provided an overview of the history of the operation of St. Mary canal. The St. Mary and Milk rivers originate in western Montana and flow north into Alberta. The 1909

Boundary Waters Treaty between Canada and the United States specified the division of flow for the two rivers. The U.S. constructed a canal to divert water from the St. Mary River in western Montana to the Milk River where it flows downstream across southern Alberta and then into eastern Montana. In 1921, rules were issued under the Order of the International Joint Commission governing how much water the Americans and Canadians could use at certain times of the year. Canada receives the right to a portion of the St. Mary River water while the United States receives a right to a portion of the Milk River. The St. Mary canal was originally designed for 24.1 $m^3 \cdot s^{-1}$, but degradation has reduced that amount to approximately 18.4 $m^3 \cdot s^{-1}$. Typically, the canal is operational from late March to September or October, during irrigation periods, although occasionally it is shut down for siphon maintenance. There have been proposals to restore the canal to the full allocation or increase the flow capacity to 28.3 $m^3 \cdot s^{-1}$.

The Western Silvery Minnow Recovery Strategy contains a description of the Milk River system that will be summarized in the RPA. There are no barriers to movement in the Milk River system within Canada, thus this species is thought to belong to one population.

There was a question about whether Western Silvery Minnow run upstream of the sampling area for spawning. The upstream portion was sampled in August, which is post spawning, so it could be possible. The habitat upstream of the sampling area may not be ideal for feeding and growing, but may be suitable for spawning. Another participant noted that the North Milk is difficult to sample in May because of high discharge and turbidity. The habitat gradient in the North and Milk rivers is higher upstream of the confluence and may prevent Western Silvery Minnow accessing further upstream. Text was added to the distribution section that says this species has not been found in the North Milk River or the Milk River upstream of its confluence with the North Milk River. The full extent of its distribution in the Milk River system cannot be confirmed because sampling has not been conducted year round. A mini Fyke net could be used for sampling, which might be easier than backpack electro-shocking at certain times of the year.

Other factors that may influence the distribution of Western Silvery Minnow were discussed. In the Yellowstone River, this species was sampled between Billings and the confluence with the Missouri River in North Dakota, a distance of about 250 river km. They were found in both cobble-gravel substrates around and downstream of Billings and sand-dominated substrates that start to appear at the North Dakota border. The habitat gradient is higher upstream but analysis of how this might affect fish distribution has not been conducted yet. There was little overlap with trout, and no overlap between Western Silvery Minnow and Rocky Mountain Sculpin (*Cottus* sp.). In Alberta, both species occur in low abundance within the zone of overlap in the Milk River, which spans about 100 river km.

Water temperature may affect the distribution of this species but there are limited data available to investigate this. The one available dataset showed that a place about midway along the length of the North Milk River was 2.5°C cooler than downstream on the Milk River at the Canada/U.S. border. It is not known whether the Milk River system is cooler now due to the influx of water from the St. Mary canal because there is no available information on water temperatures in the St Mary River prior to the canal opening in 1917. Occasional records that seemed to identify periods of drought or very low water levels were probably indicative of higher water temperatures. Given the larger volumes of water in summer now, temperatures are likely cooler than they were historically. Participants reported maximum summer water temperatures around 29°C in recent years in the Canadian and American portions of the Milk River.

Since 1917, the St. Mary River water diversion has significantly altered the flow regime in the North Milk and Milk rivers. It is not known whether the increased availability of water altered the distribution of Western Silvery Minnow in the Milk River drainage.

HISTORIC AND CURRENT ABUNDANCE AND TRENDS

Based on surveys directed at Western Silvery Minnow downstream of the confluence of the North Milk and Milk rivers in 2005, 2006 and 2007, DFO found this species was the second most abundant fish species downstream of the Town of Milk River. Upstream of the town they were not. This will be clarified in the working paper. It was noted that the most common fish is Flathead Chub (*Platygobio gracilis*).

Participants discussed catch-per-unit-effort (CPUE). They recommended the mean values reported at the end of the first paragraph should be presented as the number of fish per seine haul with an average haul distance noted. More details need to be included about the seine hauls, including mesh size and length of net. Between 1,500 and 1,600 Western Silvery Minnow were captured over the three years of surveys; actual numbers will be added to the text. The CPUE value was high because the surveys were directed at this species. The surveys were not designed to provide an estimate of abundance and the methods used and areas sampled were not comparable to historical surveys so they cannot be compared for trend analysis. The DFO surveys represented five days of sampling in any one year with no reach sampled more than twice. Comparing abundance between reaches is difficult because the habitat varies along the river. Regardless, it is known that numbers in the Canadian portion of the Milk River generally increase with distance downstream; this trend is thought to be related at least in part to the substrate which is more cobbled farther upstream and muddier downstream.

Little information is available on the abundance of Western Silvery Minnow in the U.S. portion of the Milk River. Stash (2001) sampled fishes in the Montana portion of the Milk River extensively but did not separate Plains Minnow from Western Silvery Minnow. He caught 64 *Hybognathus* in the reach upstream of the Fresno reservoir and 326 in the lowermost reach of the Milk River, which is well connected to the Missouri River, with few caught between these two reaches. DFO caught 603 Western Silvery Minnow and retained 100 under permit while sampling a stretch of the Milk River in Montana from the Canada/U.S. border to about 12 km downstream. Participants agreed that the working paper should include some information for U.S. waters upstream of the Fresno reservoir.

HABITAT REQUIREMENTS

Some research has concluded that Western Silvery Minnow requires large open stretches of water. That statement matches the conditions seen in the lower Canadian reach and upper American reach of the Milk River. There are no physical barriers that prevent Western Silvery Minnow from moving into the North Milk, although the habitat may not be suitable. Gradients and substrate composition for reaches in the Milk rivers will be referenced in this section of the working paper.

It was agreed that this section should be organized by life stage and activity according to available information. DFO has considerable habitat information for adults, some for juveniles, little for young-of-the-year (YOY), and none on overwintering habitat. Only the occasional YOY has been caught with juveniles and adults. By the fall of their first year of life, YOY reach lengths close to 40 mm. They may school with other species such as suckers, Flathead Chub and Lake Chub (*Couesius plumbeus*). In their second year of life, Western Silvery Minnow measure about 50-70 mm in length, reach maturity and spawn. Any location in the Milk River where DFO captured this species, measurements of velocity, depth and substrate were made thus it is

possible to compare habitat characteristics versus size for juvenile fish. Sample sizes are too small to conduct this sort of comparison for YOY fish. DFO collected adult fish from 140 sites along the Milk River. Many Western Silvery Minnow were caught while seining in water with limited velocity and depths of 10-15 cm. Participants agreed that the working paper should summarize the available information on range of habitat use by depth, substrate and velocity for juveniles and adults.

Hoagstrom et al. (2011) inferred that Western Silvery Minnow is a broadcast pelagic spawner. Specific spawning habitat has not been described for this species. It is thought to be similar to that described for the Rio Grande Silvery Minnow. The text was modified to reflect that. In the Yellowstone River, many Western Silvery Minnow spawned in secondary seasonal habitat.

In the Yellowstone River, up to 2,500 Western Silvery Minnow have been caught in a single set. Participants discussed results obtained from sampling cyprinids using Fyke versus seine nets. An overnight set using a mini-Fyke net caught an average of 23 fish and a maximum of 2,300 fish, of which Emerald Shiner (*Notropis atherinoides*) and Western Silvery Minnow were the first and second most common species caught, respectively. Western Silvery Minnow was found in the greatest number where the Powder River releases turbidity into the Yellowstone River. This may be related to energy or food availability and could be influenced by a diversion dam along with a habitat or temperature gradient. Their abundance tapers off as velocity and water depth increases. Research is underway to examine shifts in habitat use between the Yellowstone mainstem and its tributaries based on changes in Strontium isotope ratios. For part of their lives, a portion of the Western Silvery Minnow population occurs in both the mainstem and tributaries in a variety of macro habitats including backwater and areas only flooded during high flow. Spawning occurs in secondary channels during run-off. DFO's length-frequency data matches the Yellowstone River data.

The Yellowstone River has about eight times as many fish as the Missouri River even though the latter has been sampled twice as much. Additionally, in the Yellowstone River native fish represent 99% of the fish present compared to 92% in the Missouri River. These differences are thought to be due to the Fort Peck Dam on the Missouri River (Bob Bramblett, unpubl. data). The introduction of cold water into the Milk River system through the St. Mary canal may have a similar effect.

No changes were suggested or comments made for the text on overwintering.

RESIDENCE

Participants agreed that Western Silvery Minnow does not change its physical environment or invest in a structure therefore it does not meet the SARA definition of residence as interpreted by DFO.

RECOVERY TARGETS, RECOVERY TIMES AND MINIMUM AREA FOR POPULATION VIABILITY

Working paper: Recovery Potential Modelling of Western Silvery Minnow (*Hybognathus argyritis*) in Canada

Authors: Jennifer A.M. Young and Marten A. Koops

Presenter: Jennifer A.M. Young

Abstract[2]

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) had assessed the Western Silvery Minnow (*Hybognathus argyritis*) as Endangered in Canada (2008). Here we present population modelling to assess allowable harm, determine population-based recovery targets, and conduct long-term projections of population recovery in support of a recovery potential assessment (RPA). Our analyses demonstrated that the dynamics of Western Silvery Minnow populations are particularly sensitive to perturbations that affect survival of immature individuals (from hatch to age 2), or the fecundity of first time spawners. Harm to these portions of the life cycle should be minimized to avoid jeopardizing the survival and future recovery of Canadian populations. Based on an objective of demographic sustainability (i.e., a self-sustaining population over the long term), we propose a population abundance recovery target of 12,000 to 236,000 adult Western Silvery Minnow, requiring 25 to 497 ha of suitable habitat. In the absence of mitigating efforts, additional harm or habitat limitations, we estimate that a growing Western Silvery Minnow population will take approximately nine years to reach this recovery target if starting from a population of 1,200 adults. Recovery strategies which incorporate improvements in the most sensitive vital rates of the Western Silvery Minnow will have the greatest effect on population growth.

Discussion

Based on the earlier discussion about longevity, the author updated the model to incorporate six age classes rather than five. This change increased the mean population growth rate by less than one percent, which will not likely change the overall results by more than a rounding number.

The author provided clarification on the model results. She explained how much harm can be applied to any or all vital rates without jeopardizing survival or recovery, and that harms are cumulative. For example, if they allow 60% harm on juvenile survival that assumes no harm is occurring to adults or reproduction. If a particular threat harms all vital rates, then allowable harm is lower than if it only affects one rate.

The mean population growth rate is 2.3% (i.e., $\lambda = 2.3$) with uncertainty ranging from 0.92 to 6.5. Population growth rate is very sensitive to juvenile survival and also quite sensitive to the number of eggs of first-time spawners. Adult survival is much less important to population growth rate. The model results suggest that if adults were eliminated after they spawned the growth rate would not decline. As the growth rate declines, so too does the potential for allowable harm.

The author clarified that elasticity is an estimate based on a derivative. The elasticity increases with rising steepness in the slope of the function. In calculus, if a line is put against the curve, the further the line deviates from where it touches the curve the worse the estimate. So the authors made manual adjustments to see what the actual allowable harm would be and in the

[2] Updated following the meeting incorporating comments and reanalysis.

case of fecundity, it is a lower allowable harm than the sensitivity analysis estimated. The author clarified that the mean of deterministically-determined elasticities is the actual mean numbers while the mean of stochastically-determined elasticities is derived from thousands of trial runs. The two means are usually similar but not exactly the same because the stochastic-determined elasticities are based on numbers selected from a log-normal curve and sensitive to stochastic variation.

Minimum viable population (MVP) was defined as the population size that would result in a 0.1% probability of extinction.The authors considered different levels of catastrophe to develop extinction curves. If catastrophes occurred at a rate of 15% per generation (6% annually) then MVP was 12,000 adults (7,000-21,600). The MVP simulations assumed an extinction threshold of one adult female (i.e., two adults). A participant asked that the model be re-run using an extinction threshold of 50 and 500, to match the usual rule of thumb about minimum population size to maintain genetic diversity. They added that the population estimate for Plains Minnow is about 20,000 adult individuals.

Another participant asked if it matters that the sex ratio is different from 50:50. The immediate difference would be that the total fecundity would be multiplied by something other than one-half. This model assumes there are enough males to breed with available mature females. The fecundity is halved in order to count the number of females that will go through the reproductive cycle and replace themselves in the next generation. A participant reported that for Plains Minnow, 135 fish were sampled and the sex ratio was within one fish of 50:50. Research by Galat et al. (2005) investigated spawning conditions and related habitat for Western Silvery Minnow in the Yellowstone River. They reported capturing 82 milting and 123 gravid fish. Participants asked the author to re-run the Population Viability Analysis (PVA) modelling analysis for Western Silvery Minnow using probabilities of extinction of 1% and 5% and extinction thresholds of 20 and 50 individuals.

Participants discussed the estimated minimum area for population viability (MAPV) based on the modelling results. MAPV was calculated for each age-class and then summed across all age classes for the population. Based on a target MVP of 12,000 adults, under a 0.15 probability of catastrophe per generation, a population of that size was predicted to require 25.3 ha of suitable habitat, not taking into account any overlapping of individual habitats. A participant reported there is approximately 700 hectares of available habitat for Western Silvery Minnow in the Canadian portion of the Milk River system if one uses an average stream discharge of 20 $m^3 \cdot s^{-1}$ as a measure of suitable habitat. During winter, when discharge rates are lower, they are restricted to small pools. It may be possible to estimate a minimum habitat length using minimum velocity and minimum hours or days for hatching out; this method has been used for other *Hybognathus* species. It is not known if this species travels across the Canada/U.S. border but participants agreed that available habitat should also include the Milk River from the border to 75 km downstream. In low-water years, Western Silvery Minnow does not show up in reservoirs as larger-bodied fish do.

Western Silvery Minnow is not a sedentary species and it has been reported in the literature they need at least 100 km of river to complete their life cycle. One participant shared data indicating that Western Silvery Minnow spawn in tributaries of the Yellowstone River. As this species resides primarily in large rivers, their appearance in tributaries strongly suggests that they move some distance to spawn. Another participant hypothesized that in the American side of the lower Milk River this species spawns upstream, the eggs drift downstream towards the Fresno Reservoir, hatch as they hit the reservoir and then spend the next two years working their way upstream where they spawn for the first time. If this hypothesis is correct there would be smaller fish downstream and larger fish upstream in this portion of the Milk River. There are

insufficient data currently available to test this hypothesis. Regardless, several participants thought this hypothesis was highly probable.

The Western Silvery Minnow is closest, reproductively, to the Rio Grande Silvery Minnow or Plains Minnow. Bestgen et al. (2003) reported that the Rio Grande Silvery Minnow can swim the equivalent of 50 km in less than 72 hours. A study of Plains Minnow by Platania and Altenbach (1998) indicated that 70-200 km of river was needed to complete hatching. A study conducted in the Canadian River by Bonner and Wilde (2000) reported that given current velocities and length of time required for eggs to hatch and larvae to swim out of the main current, an approximate distance of 218 km may represent the minimum length of unimpounded river necessary for completion of the life history of prairie stream cyprinids. Dudley and Platania (2007) experimented with passive drifting particles as a surrogate for eggs and showed a mean transportation distance of 139 km in the Rio Grande River required 82 hours (at 120 $m^3 \cdot s^{-1}$) and 138 hours (at 20 $m^3 \cdot s^{-1}$) which is similar to the length of time required to complete larval development (4 days at 25°C water temperature for Plains Minnow and Rio Grande Silvery Minnow, and 7 days at 20°C and 10 days at 15°C for Rio Grande Silvery Minnow). River sections less than 100 km in length had lost their broadcast spawners.

On the basis of the available data for Western Silvery Minnow and other closely-related species, participants agreed that this species likely requires highly-connected habitat (i.e., continuous river) more than 100 km in length.

The author stated that the extinction risk increases exponentially when habitat is limited or of low quality, or any other resource is limited. Based on the sensitivity analysis, the best strategy for recovery is to improve survival of immature individuals. The modelling results concluded that in the absence of mitigating efforts, additional harm or habitat limitations, a Western Silvery Minnow population would need about nine years to reach to reach a recovery target of 12,000 adults if it started at 1,200 adults. However, as the amount of harm increases so does the timeframe for recovery. Probability of persistence is reduced when habitat-related density dependence is included. A reach of sufficient size is needed to ensure a suitable number of eggs get to suitable habitat and hatch. The model indicates that this species is sensitive to that shift. The author agreed to add a comment to the modelling document about habitat requirements for a highly-mobile species such as the Western Silvery Minnow and the need for long, continuous habitat.

THREATS TO SURVIVAL AND RECOVERY

The meeting chair explained how threats would be assessed. Participants agreed that only the Milk River below the confluence would be evaluated. A participant suggested that threats be presented in the working paper in decreasing order of importance if appropriate. The threats section in the working document was reviewed and discussions related to each threat type are described below. Some threats were added, re-named or re-organized.

Species Introductions

There are Trout-Perch (*Percopsis omiscomaycus*) in the Milk River, around and downstream of the Town of Milk River. They are thought to be introduced from the Saskatchewan drainage. It will be verified whether Trout-Perch are introduced or native. Northern Pike (*Esox lucius*) were introduced into a tributary of the Milk River and it is likely that some escaped into the mainstem. Whether they were native to the Milk River is unknown. The American participant said they are not considered native in the Missouri River, therefore not native in the Milk River either. One participant noted that if the distribution of Northern Pike overlaps with Western Silvery Minnow then they are a significant threat but another participant reported that the Milk River is poor

habitat for Northern Pike and they are not abundant. The group agreed with the list of introduced species and will also include Spottail Shiner. Participants discussed native species that prey on Western Silvery Minnow. Channel Catfish (*Ictalurus punctatus*) occur downstream of the Fresno Reservoir.

The Chair suggested adding text for non-fish species such as Northern Crayfish (*Orconectes virilis*). *Didymosphenia geminata* was not included as a threat because it is eaten by Western Silvery Minnow.

Species introductions are known to occur so this threat was rated as Known and its impact on Western Silvery Minnow as Low to High depending on the species introduced. The spatial and temporal extent of this threat was rated as Widespread and Chronic.

Changes in Geomorphology

Changes in geomorphology of the Milk River, including channelization, have occurred over the past 100 years and continue to this day. A participant reported that cross sections of the river and analysis of these changes have been conducted since 1910. One such analysis was done within the range of Western Silvery Minnow in 2009-2010 by AMEC Earth & Environmental Ltd for the Milk River Watershed Council (T. Clayton, pers. comm.). It is known that there have been changes in geomorphology response to flow augmentation and that the impacts (i.e., increase in river width over time, erosional capability, migration of the channel or oxbow, changes in shape of the river) were greater in the North Milk River than downstream of the confluence. They calculated the increase in width over time for the channel and it addressed erosional capability, ice, and migration of the channel. There are numerous oxbows on the Milk River. These changes in geomorphology need to be summarized in the working paper.

Participants discussed lateral habitat, such as side channels and backwaters, and their importance for this species. Historically, seasonal backwater habitats in the Milk River system were more frequent and longer in duration. As a result of flow augmentation from the St. Mary canal, the Milk River has been down-cut so it is now deeper and its shape has changed. It is a singular oversized channel, with few lateral or side channels, which rarely goes over its banks onto the floodplain. Historically, overbank flows may have been 30-40 $m^3 \cdot s^{-1}$ which is now well within augmentation flow levels. Isolated oxbows are now probably only available during high water events. The normal flow at the Town of Milk River is 18 $m^3 \cdot s^{-1}$ in June; in 2005 a flood event peaked out at 257 $m^3 \cdot s^{-1}$. Loss of connectivity to oxbows decreased lateral connectivity to the floodplain, except during exceptionally high water events, thereby reducing the availability of habitat. These changes will be described in the working paper.

The Rio Grande Silvery Minnow has episodic recruitment when the floodplain is inundated. As lateral connectivity in the Milk River has been reduced, Western Silvery Minnow in Alberta has made use of seasonal habitats in the mainstem in the form of low-velocity waters downstream of sandbar islands. There is now 300 km of open reach available. It may be the case that this species is more successful spawning in side channels or during overland flooding, but because the reach is larger it may not be as impacted by loss of that habitat.

On this basis of this discussion, participants added a section on changes in geomorphology. It explains how augmentation of flows from the St. Mary canal for almost a century has fundamentally changed the channel and floodplain morphology in the North Milk and Milk rivers thereby reducing the frequency of overbank flooding and lateral habitat connectivity. Modified channel morphology has contributed to the decline of the closely-related Rio Grande Silvery Minnow. On the basis of this correlative study, participants decided that the impact of this threat to Western Silvery Minnow is likely Low to Medium.

Changes in Habitat Quality and Availability

Participants discussed how the augmentation in flow resulting from the diversion has likely changed the substrates, water depths and water velocities of the Milk River leading to a decline in habitat quality for Western Silvery Minnow. Downstream effects of the diversion on the establishment of cottonwood forests (riparian vegetation) on the Milk River have also been reported (Bradley 1982). Cottonwood are limited by access to water. The results of Bradley's research will also be mentioned in the working paper. Participants rated the impact of this threat to Western Silvery Minnow as Low to Medium.

Changes in Flow Regulation Associated with the Diversion Canal

No changes were made to the text for this section though one participant may have comparative information on naturalized versus actual flow that might be useful. Changes in flow resulting from the St. Mary diversion are Known and the impact is High.

Dam Construction and Operation

Participants decided to combine dam construction and operation. Construction of a dam would pose a barrier to fish movements, create a reservoir, and result in loss of habitat for the dam footprint. Operation of a dam would affect flow and water temperature.

A dam is proposed for just downstream of the Milk River confluence which would consist of a dam, emergency spillway, tunnel and gate, and would allow regulated flows. One of the purposes of the proposed dam is to divert some water to the Town of Milk River. If it goes forward sometime in the future its construction may be negligible for Western Silvery Minnow because their known distribution is downstream of the proposed dam site. However, regulated flows and changes in water temperature from operation of the dam could be a concern. A low-head weir would have only a moderate impact while a large dam would have high impact.

Off-stream proposals have also been considered in the Milk River system. One is to build a dam on Shanks Lake which drains into the North Milk River by way of Shanks Creek. This proposal could affect flow in the North Milk River but the dam footprint would not represent a threat to Western Silvery Minnow. This information will be summarized in the working paper.

It was noted that the Cowley references need to be checked for spelling throughout the document.

Participants rated the likelihood of dam construction and operation as Unknown because there is no dam within this part of the Milk River yet but if one were built the impact would be Medium to High.

Groundwater Extraction

Ranchers use groundwater for domestic purposes so it should be mentioned in this section. Participants agreed that the threat likelihood of groundwater extraction is Known and its impact ranges from Low to High depending on when it occurs and how much it affects river flow.

Surface Water Extraction

Irrigation

Participants thought that the loss of water in the Milk River for irrigation could impact the availability of habitat more than groundwater extraction through wells. However, if strong linkages exist between groundwater and surface water then excessive diversion of groundwater could have a more significant impact than this threat. There was a general consensus on the

description of this threat in the working paper. Irrigation as a possible threat is Known but its impact was rated Low because it occurs only during the period of flow augmentation (from late March or early April through late September or mid-October). The international agreement and water rates control how much water can be removed from the river so it is unlikely the level of extraction during normal augmented operating flows would ever get high enough to impact Western Silvery Minnow.

Non-irrigation

Participants wanted to know the volume of water used by the Town of Milk River as it could represent a significant proportion of the total during periods of low flow. Surface water extraction for non-irrigation was rated as Known and its impact was rated as ranging from Low to High depending on whether it occurs during the period of flow augmentation or during the period of low natural flow.

Livestock Use of Flood Plain

Livestock are known to use the flood plain. A participant noted that if cattle trample the riverbank edges that would increase sedimentation. As Western Silvery Minnow prefers turbid water, that activity may not pose a direct threat. Some text will be added to this section to indicate that livestock overgrazing of the flood plain can result in destabilization of stream banks and degradation of the riparian vegetation community. The effects of this threat on Western Silvery Minnow are unknown although participants thought its impact is probably Low.

Contaminants and Toxic Substances

The title of this subsection was changed from "pollution" to "contaminants and toxic substances". This threat includes both point source and non-point source contamination. More water quality data have been collected since the recovery plan was drafted. There have been spikes in coliform counts (non-point source contaminant input) near Writing-on-Stone Provincial Park coming from tributaries alongside sprayed fields. Water quality data were collected from a number of locations in the park which resulted in closure of the park beach. Recent information on water quality will be added to the working paper. Participants agreed that the occurrence of both point source contamination and non-point source contamination in the Milk River is Known and their impacts on Western Silvery Minnow range from Low to High depending on the substance released, concentration and the time of the year.

Anoxia

One participant noted that overwintering habitat can be reduced to standing pools. If those pools are not deep enough or maintained by groundwater, they could potentially freeze to the bottom and negatively impact Western Silvery Minnow. Other participants said that even though surface flow may not be detectable, the porosity of cobble substrates still permits water movement through the ground. In areas without cobbles or boulders, interstitial spaces are limited so Western Silvery Minnow must winter above the substrate. The group agreed that the likelihood and impact of anoxia is Known and High, respectively, for Western Silvery Minnow, particularly during periods of low flow (e.g., when the diversion is undergoing maintenance or in winter).

Participants recommended checking for consistency in the oxygen concentration information presented in the Rocky Mountain Sculpin and Western Silvery Minnow RPA documents.

Drought

Extreme drought occurs in southern Alberta from time to time. It is likely Western Silvery Minnow in the Milk River experience winterkill during periods of drought. The effects of this threat are most dominant when flow augmentation is eliminated during periods of maintenance work. Participants rated the likelihood and impact of this threat as Known and High, respectively.

Scientific Sampling

Scientific sampling occurs from time to time but the numbers of fish taken are very low relative to the abundance of this species in the Milk River. For that reason, the impact of this threat was rated as Low.

No revisions were made to the text in this section of the working paper.

Climate Change

Participants did not to assess climate change because although it has the potential to impact Western Silvery Minnow, the likely impact of this threat is unknown.

MITIGATIONS AND ALTERNATIVES

Some sentences were added to this section based on the Pathways of Effects (POEs) document reviewed for the Pugnose Shiner (*Notropis anogenus*) RPA. Participants looked at two POEs and their associated mitigation measures that were identified as threats for Western Silvery Minnow to assess their suitability in the Milk River system. The first was a land-based activity (livestock grazing) and the second was an in-water activity (water extraction).

Four mitigation measures (8-1 to 8-4) were presented for the livestock grazing pathway in the POEs document. Measure 8-1 would prohibit or limit livestock access to banks or areas and is unlikely to work on the Milk River, according to one participant, because it would require fencing 300 river km. Limiting access through changes in grazing practices (e.g., offstream watering, limited stays, limited densities, rotational grazing, etc.), as advocated by the Alberta Riparian Habitat Management Society (commonly known as "Cows and Fish"), is a reasonable mitigation measure for Western Silvery Minnow along the Milk River. Mitigation measure 8-2 entails riparian vegetation plantings and is being tried out on the Milk River. It is not clear that adding or establishing in-stream structure would be beneficial for this species so mitigation 8-3 was not deemed reasonable. Mitigation measure 8-4 would stabilize exposed soils and stream banks. Participants thought it could be combined with 8-2 because they seem similar although 8-4 only appears to apply to erosion.

Participants then reviewed the two mitigation measures for water extraction presented in the POEs document. Measures 12-1 and 12-2 relate to isolating temporary in-water work zones, managing flow withdrawal and discharge to prevent erosion and sediment release, and using screens to prevent entrainment. Both measures were thought to be appropriate for Western Silvery Minnow except for energy dissipation measures identified for 12-1.

Following the meeting, the chair will examine the POEs document for any additional pathways that may be applicable, and mitigations that would be useful, for this species in the Milk River.

SOURCES OF UNCERTAINTY

Participants agreed this section would be combined with the Data and Knowledge Gaps section and that it would also include gaps in knowledge related to the modelling analysis.

OTHER CONSIDERATIONS

Participants discussed and added information to this section about ongoing Canada/U.S. water management of the St. Mary and Milk rivers, including flow rates, water volumes and apportioning.

REFERENCES CITED

Bestgen, K.R., Mefford, B., Bundy, J., Walford, C., Compton, B., Seal, S., and Sorensen, T. 2003. Swimming performance of Rio Grande silvery minnow. Final Report to U. S. Bureau of Reclamation, Albuquerque Area Office, New Mexico. Colorado State University, Larval Fish Laboratory Contribution 132. 70 p.

Bonner, T.H., and Wilde, G.R. 2000. Changes in the Canadian River fish assemblage associated with reservoir construction. J. Freshwater Ecol. 15: 189-198.

Bradley, C.E. 1982. Modified meandering river regimes – effects on Plains Cottonwood regeneration: Milk River valley, southeast Alberta and northern Montana. Thesis (M.Sc.) University of Calgary, Calgary, AB. 124 p.

Coker, G.A., Ming, D.L., and Mandrak, N.E. 2010. Mitigation guide for the protection of fishes and fish habitat to accompany the species at risk recovery potential assessments conducted by Fisheries and Oceans Canada (DFO) in Central and Arctic Region. Version 1.0. Can. Manuscr. Rep. Fish. Aquat. Sci. 2904: vi + 40 p.

DFO. 2007a. Revised Protocol for Conducting Recovery Potential Assessments. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/039.

DFO. 2007b. Documenting habitat use of species at risk and quantifying habitat quality. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2007/038.

Dudley, R.K., and Plantania, S.P. 2007. Flow regulation and fragmentation imperil pelagic-spawning riverine fishes. Ecol. Applications 17: 2074-2086.

Galat, D.L., Berry, C.R. Jr., Gardner, W.M., Hendrickson, J.C., Mestl, G.E., Power, G.J., Stone, C., and Winston, M.R. 2005. Spatiotemporal patterns and changes in Missouri River fishes. Am. Fish. Soc. Symposium 45: 249-291.

Hoagstrom, C.W., Brooks, J.E., and Davenport, S.R. 2011. A large-scale conservation perspective considering endemic fishes of the North American plains. Biol. Conserv. 144: 21-34.

Nelson, J.S., and Paetz, M.J. 1992. The fishes of Alberta. Second Edition. The University of Alberta Press, Edmonton, AB. 437 p.

Ostrand, K.G., and Wilde, G.R. 2001. Temperature, dissolved oxygen, and salinity tolerances of five prairie stream fishes and their role in explaining fish assemblage patterns. Trans. Am. Fish. Soc. 130: 742-749.

Pflieger, W.L. 1997. The fishes of Missouri, revised edition. Missouri Department of Conservation, Jefferson City, MO. 372 p.

Platania, S.P., and Altenbach, C.S. 1998. Reproductive strategies and egg types of seven Rio Grande Basin Cyprinids. Copeia 1998: 559-569.

Robison, H.W., and Buchanan, T.M. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville, AR. 536 p.

Scott, W.B., and Crossman, E.J. 1973. Freshwater fishes of Canada. Fish. Res. Board Can. Bull. 184. 966 p.

Stash, S.W. 2001. Distribution, relative abundance, and habitat associations of Milk River fishes related to irrigation diversion dams. Thesis (M.Sc.) Montana State University, Bozeman, MT. 67 p.

Sublette, J.E., Hatch, M.D., and Sublette, M. 1990. The Fishes of New Mexico. University of New Mexico Press, Albuquerque, New Mexico. 393 p.

APPENDIX 1: TERMS OF REFERENCE

Terms of Reference

Recovery Potential Assessment (RPA) of Western Silvery Minnow

Central and Arctic Regional Advisory Meeting

Lethbridge, Alberta

1:00 p.m. to 4:30 p.m. (MDT) on March 23, 2011 and

8:30 a.m. to 3:00 p.m. on March 24, 2011

Chair: Kathleen Martin

Background

In June 2003, the Western Silvery Minnow (*Hybognathus argyritis*) was added to Schedule 1 of the *Species at Risk Act* (SARA) as Threatened. A recovery strategy was finalized in February 2008. In April of that year the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-assessed the status of Western Silvery Minnow as Endangered. The reason for this designation is because this species is restricted to the Milk River in southern Alberta, a region characterized by drought conditions of increasing frequency and severity. Changes in flow regimes associated with the St. Mary's diversion canal and proposed water storage projects have the potential to significantly affect the survival of the species. Rescue effect from U.S. populations is not possible.

In advance of making a listing decision about whether to up-list Western Silvery Minnow on Schedule 1 to Endangered, Fisheries and Oceans Canada (DFO) Science has been asked to undertake a Recovery Potential Assessment (RPA). DFO Science developed the RPA framework to provide the information and scientific advice required for the Department to meet various requirements of the SARA. The information in the RPA may be used to inform both scientific and socio-economic elements of the listing decision, as well as development of a recovery strategy and action plan, and to support decision-making with regards to the issuance of permits, agreements and related conditions, as per sections 73, 74, 75, 77 and 78 of the SARA.

This advisory meeting is being held to assess the recovery potential of Western Silvery Minnow. The resulting RPA Science Advisory Report (SAR) will summarize the historic and current understanding of the distribution, abundance and trend of this species, along with recovery targets and times to recovery while considering various management scenarios. The current state of knowledge about habitat requirements, threats to both habitat and Western Silvery Minnow, and measures to mitigate these impacts, will also be included in the SAR. At this stage in the SARA process for Western Silvery Minnow, the information in the RPA may be used to inform the listing decision, development of an action plan and to support decision-making with regards to the SARA agreements and permits.

Objectives

The intent of this meeting is to assess the recovery potential of Western Silvery Minnow using the RPA framework outlined in the Revised Protocol for Conducting Recovery Potential Assessments (available at: http://www.dfo-mpo.gc.ca/csas/Csas/status/2007/SAR-AS2007_039_e.pdf). The advice will be provided to the DFO Minister for her consideration in meeting various requirements of the SARA including any listing decision for this species.

Products

The meeting will generate a proceedings report summarizing the deliberations of the participants. This will be published in the Canadian Science Advisory Secretariat (CSAS) Proceedings Series on the CSAS website. There will be CSAS Research Document(s) produced from the working paper(s) presented at the meeting. Advice from the meeting will be published in the form of a SAR.

Participation

Experts from DFO, provincial and U.S. state governments and academia have been invited to participate in this meeting.

APPENDIX 2: MEETING PARTICIPANTS

Name	Affiliation
Robert Bramblett	Montana State University, Bozeman, MT
Mike Bryski	Alberta Environment and Sustainable Resource Development, Lethbridge, AB
Terry Clayton	Alberta Environment and Sustainable Resource Development, Lethbridge, AB
Holly Cleator	Fisheries and Oceans Canada, Science, Winnipeg, MB
Kathleen Martin	Fisheries and Oceans Canada, Science, Winnipeg, MB
Shane Petry	Fisheries and Oceans Canada, Species at Risk, Lethbridge, AB[3]
Doug Watkinson	Fisheries and Oceans Canada, Science, Winnipeg, MB
Jennifer Young	Fisheries and Oceans Canada, Science, Winnipeg, MB

[3] Current affiliation: Alberta Environment and Sustainable Resource Development, Medicine Hat, AB

APPENDIX 3: MEETING AGENDA

AGENDA

Recovery Potential Assessment for Western Silvery Minnow

DFO office, 704 – 4th Avenue South, Lethbridge, AB

Chair: Kathleen Martin

23 March 2011

1:00 Welcome and introductions (Martin)

1:10 Purpose of the meeting (Martin)

1:20 Species biology and ecology

1:40 Historic and current distribution and trends

1:55 Historic and current abundance and trends

2:15 Residence

2:30 Information to support identification of critical habitat

3:10 *Coffee break*

3:30 Modelling presentation (Young) and discussion

4:15 Recovery targets

4:30 End of day

24 March 2011

8:30 Recap of first day (Martin)

8:45 Recovery targets (continued)

9:15 Threats to survival and recovery

10:00 *Coffee break*

10:20 Limiting factors for population recovery

10:30 Mitigations and alternatives

11:15 Allowable harm

12:00 *Lunch*

1:15 Data and knowledge gaps

1:25 Sources of uncertainty

1:35 Abstract and conclusions for Res Doc, summary bullets for Science Advisory Report

2:35 Maps/tables/figures and literature cited

2:50 Concluding remarks / next steps (Martin)

3:00 Meeting adjourns